

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
8 November 2001 (08.11.2001)

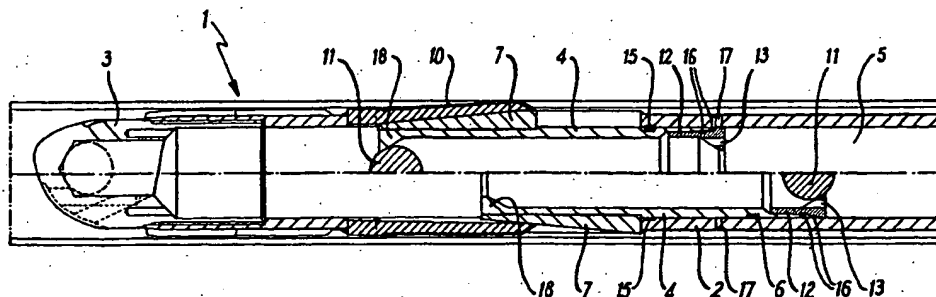
PCT

(10) International Publication Number

WO 01/83932 A1

- (51) International Patent Classification<sup>7</sup>: E21B 7/20, 17/14, 43/10
- (21) International Application Number: PCT/GB01/01512
- (22) International Filing Date: 2 April 2001 (02.04.2001)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
0010378.8 28 April 2000 (28.04.2000) GB
- (71) Applicants (for all designated States except US): **BBL DOWNHOLE TOOLS LIMITED** [GB/GB]; Suite 12, McNeill Business Centre, Greenbank Crescent, East Tullos, Aberdeen AB12 3BG (GB). **BAIN, James** [GB/GB]; 20 West Park Crescent, Inverbervie, Montrose DD10 0TX (GB). **HAITES, Binnert, Ruerd** [CA/GB]; 32 Cairn Road, Bieldside, Aberdeen AB15 9AL (GB).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): **TULLOCH, Rory, McCrae** [GB/GB]; 20 Ashley Park North, Aberdeen AB10 6SF (GB).
- (74) Agent: **KENNEDYS PATENT AGENCY LIMITED**; Floor 5, Queens House, 29 St Vincent Place, Glasgow G1 2DT (GB).
- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:  
— with international search report
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: EXPANDABLE APPARATUS FOR DRIFT AND REAMING A BOREHOLE



(57) Abstract: An expandable reamer shoe is provided for use with expandable casing in a borehole. The reamer shoe has a number of reaming members in the form of blades which remain closed against the body of the shoe when inserted through casing, and can then be expanded to underream below the casing. Additionally, the expandable reamer shoe is made substantially of a drillable material so that the borehole can be extended beyond the point reached by the expandable reamer shoe.

WO 01/83932 A1

BEST AVAILABLE COPY

1 Expandable Apparatus for Drift and Reaming a Borehole

2

3 This invention relates to an expandable reamer shoe which  
4 can be used to drift and ream drilled well bores, as are  
5 typically used in oil and gas production.

6

7 When constructing a well bore, it is standard practice to  
8 drill in intervals. Firstly, a large surface hole is  
9 created into which casing is installed to act as a lining  
10 in the bore. Cement can then be displaced between the  
11 external surface of the casing and the interior of the  
12 well bore in order to structurally support the casing.  
13 In order to drill the next and deeper section of the bore  
14 it is common practice to use a smaller drill bit attached  
15 to a drill string which can be lowered through the  
16 previously installed casing in the first section of the  
17 bore. Consequently, the next section of the bore, and  
18 the casing installed within it, has a smaller diameter to  
19 that which is above it. Further sections of well are  
20 then lined with a length of even smaller casing which  
21 runs back to the surface and is inserted into the bore by  
22 the above described method. Several sections of hole may  
23 be drilled before the final back to surface section, near

1 the production zone, is drilled and lined with liner,  
2 which is hung inside the bore on the last string of  
3 casing, rather than being run back to the surface like  
4 the casing sections above it.

5  
6 There have been a number of methods recently described  
7 whereby steel casing (US Patent No 5667011 and WO  
8 93/25799) can be expanded after it has been run into a  
9 bore. Expandable casing overcomes the problem inherent  
10 to conventional casing whereby as a consequence of the  
11 normal installation procedure, the diameter of the  
12 sections of casing decreases with depth in the well-bore.  
13 However, if the well bore is not at the planned diameter  
14 when the casing is expanded in the hole which may occur  
15 for example, due to hole contraction after the drilling  
16 run, there is a danger that the next string of casing  
17 when expanded, will not go out to the full size, due to  
18 the restricted hole diameter outside the casing.

19  
20 When requiring to drill a hole below the casing, of a  
21 size larger than the bore of the casing, it is standard  
22 practice to use a drill string with an underreamer and  
23 pilot bit. Underreamers are comprised of a plurality of  
24 expandable arms which can move between a closed position  
25 and an open position. The underreamer can be passed  
26 through the casing, behind the pilot bit when the  
27 underreamer is closed. After passing through the casing  
28 the underreamer can be opened in order to enlarge the  
29 hole below the casing. It is not feasible when running  
30 expanded casing, to drill down the casing using an  
31 underreamer attached, as underreamers are not drillable,  
32 that is they can only be used when there is a certainty  
33 that further sections of the bore will not be drilled, as

1 the subsequent drill bit or casing drill shoe would have  
2 to pass through the underreamer in order to advance.  
3 This is extremely difficult as underreamers are required  
4 to ream and remove hard rock material and typically  
5 comprise hard, resilient materials such as Tungsten  
6 Carbide or steel. Drilling through an in-place  
7 underreamer may result in damaging the drill bit or the  
8 casing drill shoe, adversely affecting the efficiency of  
9 any further drilling.

10

11 Other methods include the use of an expandable bit,  
12 rather than an underreamer with a pilot solid crown bit,  
13 and also a bi-centre bit.

14

15 It is therefore recognised in the present invention that  
16 it would be advantageous to provide a reamer shoe which  
17 can be used in conjunction with expandable casing and  
18 which is itself expandable, and can drift and ream a  
19 drilled section prior to expansion of the casing.

20

21 It is an object of the present invention to provide an  
22 expandable reamer shoe which can be attached to casing  
23 and which can drift and/or ream a previously drilled hole  
24 regardless of whether the casing is being advanced by  
25 rotation and/or reciprocation of the reamer shoe.

26

27 It is further object of the present invention to provide  
28 an expandable reamer shoe which can be used with either  
29 expandable casing or standard casing when desired.

30

31 It is a yet further object of the present invention to  
32 provide an expandable reamer which is constructed from a  
33 material which allows a casing drill shoe or drill bit to

1 drill through it such that the drill shoe or drill bit is  
2 not damaged and can progress beyond the point reached by  
3 the expandable reamer shoe within the well bore.

4  
5 According to a first aspect of the present invention  
6 there is provided a reamer shoe for mounting on a casing  
7 string, the reamer shoe having a plurality of reaming  
8 members wherein said reamer shoe is constructed from a  
9 relatively soft drillable material, wherein the plurality  
10 of reaming members are moveable between a first and  
11 second position, and wherein the reaming members are  
12 closed in the first position and expanded in the second  
13 position.

14  
15 Optionally the expandable reamer shoe can act as a drift.

16  
17 Preferably the plurality of reaming members are in the  
18 form of blades.

19  
20 Optionally each of the blades has a hard facing applied  
21 to the outer surface.

22  
23 In one embodiment, the reaming members move from the  
24 first closed position to the second expanded position by  
25 virtue of the movement of an activating piston.

26  
27 Most preferably said activating piston defines an  
28 internal bore.

29  
30 Preferably movement of the activating piston is provided  
31 by an increase in hydrostatic pressure.

32

1 Preferably the increase in hydrostatic pressure is  
2 provided by an obstructing means within the internal bore  
3 of the activating piston.  
4  
5 Most preferably said obstructing means is a deformable  
6 ball or dart.  
7  
8 Preferably the reaming members are fully expanded when  
9 the ball communicates with a seat formation in the  
10 internal bore.  
11  
12 Preferably the ball is held inside the bore of the  
13 activating piston by a retainer ring.  
14  
15 Preferably the retainer ring has a plurality of by-pass  
16 ports which allow fluid and mud to pass through the  
17 retainer ring.  
18  
19 Optionally the activating piston or retainer ring is  
20 adapted to receive a retrieval tool such as a spear or  
21 overshot.  
22  
23 Preferably the activating piston has an external split  
24 ring mounted around the outside diameter.  
25  
26 Preferably the split ring can communicate with a groove  
27 in the body of the reamer shoe, wherein the activating  
28 piston is prevented from moving when the split ring is in  
29 communication with said groove.  
30  
31 Preferably a plurality of ramps are located externally to  
32 the activating piston.  
33

1 Preferably the activating piston ramp segments, split  
2 ring, ball, retainer ring and float valve are drillable.

3

4 In a second embodiment concept of the present invention,  
5 the reaming members move from the first closed position  
6 to the second expanded position by virtue of a  
7 hydrodynamic pressure drop between the interior and  
8 exterior of the reamer shoe.

9

10 Most preferably said hydrodynamic pressure drop is  
11 created by one or more nozzles which may be attached to  
12 the lowermost end of the reamer shoe.

13

14 Preferably the reaming members are held in the first  
15 closed position by a plurality of leaf springs.

16

17 Preferably in the second expanded position the reaming  
18 members are locked in position by a first and second  
19 retaining block at either end.

20

21 Optionally the reamer shoe may contain a rupture means  
22 such as a burst disc, wherein upon rupturing, the rupture  
23 means permits the flow area of fluid from the interior of  
24 the reamer shoe to the exterior to be increased for ease  
25 of passage of cement, when cementing the casing, after  
26 reaming to bottom.

27

28 Optionally the expandable reamer shoe may have a  
29 cementing float valve fitted in the nose or the bore of  
30 the body.

31

1 According to a second aspect of the present invention  
2 there is provided a method of inserting expandable casing  
3 into a borehole, comprising the steps of;  
4 a) running a first section of expandable casing into a  
5 pre-drilled borehole, expanding and then cementing  
6 (if required) the expandable casing in place,  
7 b) underreaming under the in-place casing using a  
8 standard underreamer and pilot bit or an expandable  
9 bit or bi-centre bit,  
10 c) running a second length of expandable casing through  
11 the in-place casing with an expandable reamer shoe  
12 to ream down by rotation and/or reciprocation to  
13 guarantee the hole is at the expected size  
14 d) After reaming down, if needed, the expandable casing  
15 can be expanded and then cemented (if required) to  
16 create a slimhole or even a mono-bore well. The  
17 expandable reamer shoe, as well as having expandable  
18 blades, can also be designed to have its body  
19 expanded in the same manner as the casing above it.  
20  
21 The method may further comprise the step of running a  
22 subsequent section of casing through the in-place section  
23 of expandable casing after drilling through the apparatus  
24 of the first aspect to create a new hole or even to use a  
25 casing drill shoe to drill out the nose of the expandable  
26 reamer shoe for drilling and casing simultaneously.  
27  
28 In order to provide a better understanding of the  
29 invention, an example first embodiment of the invention  
30 will now be illustrated with reference to the following  
31 Figures in which;  
32

1 Figure 1 illustrates a cross sectional view of an  
2 expandable reamer shoe in accordance with the present  
3 invention,  
4 Figure 2 illustrates an external view of an expandable  
5 reamer shoe,  
6 Figure 3 and 4 illustrate embodiments of the grooves  
7 which co-operate with the split ring of the activating  
8 piston, in an alternative cross sectional view expandable  
9 reamer shoe,  
10 Figure 5 illustrates the nose of an expandable reamer  
11 shoe with a float valve included,  
12 Figures 6 and 7 illustrate alternative retainer rings for  
13 use with of an expandable reamer shoe,  
14 Figure 8 is a cross sectional view of an alternative  
15 second embodiment of an expandable reamer shoe,  
16 Figure 9 and 10 illustrate the nose of the expandable  
17 reamer shoe of Figure 8 with a float valve option, and;  
18 Figures 11 and 12 illustrate an alternative cross  
19 sectional view of the expandable reamer shoe of Figure 8.

20

21 Referring firstly to Figure 1, an expandable reamer shoe  
22 which can drift and ream a drilled section of well bore  
23 is generally depicted at 1 and is comprised of a  
24 cylindrical body (2) with an eccentric nose with ledge  
25 riding capability (3). The body (2) contains an  
26 activating piston (4) which is moveable and which defines  
27 an internal bore (5). The activating piston (4) has a  
28 split ring (6) which is fitted onto the outside diameter  
29 of the piston (4). The body (2) is made from steel and  
30 has hard facing reaming members (6) which can be seen in  
31 Figure 2 applied to the leading end for reaming the inner  
32 most section of the drilled hole.

33

1 Upon assembly of the tool (1), the activating piston (4)  
2 with the split ring (6) mounted thereon will be inserted  
3 into the bore (5) of the body (2). Simple service  
4 tooling is used to install the split ring (6) into the  
5 bore (5) of the body (2). The piston (4) would be slid  
6 down to the position shown on the lower side of the  
7 centre line of Figure 1. A plurality of ramp segments  
8 (7) would then be welded onto the outside of the piston  
9 (4) through slots (8) in the wall of the body (2). The  
10 slots (8) can be seen in more detail on the external view  
11 of the reamer shoe (1) seen on Figure 2.  
12

13 It can be seen from Figures 3 and 4 that the piston (4)  
14 has six slots for the location of six ramp sections (7)  
15 each of which corresponds with one of six external blades  
16 (10). When the tool (1) is to be used as a reamer, the  
17 blades (10) have hard facing pre-applied, for example,  
18 hard or super hard metal or diamond. However when the  
19 tool (2) is to be used solely as a drift, the blades (10)  
20 will not need to have cutting grade hard facing. The  
21 piston (4), split ring (6) and ramp segments (7) are all  
22 made from a drillable material such as aluminium alloy.  
23 The blades (10) and body (2) are made from an material of  
24 medium hardness, such as alloy steel.  
25

26 A deformable ball or dart (11) is then be dropped into  
27 the bore (5) of the piston (4). The ball or dart (11),  
28 which would typically be a rubber/plastic or  
29 rubber/plastic coated ball can be seen on the lower side  
30 of the centre line on Figure 1. A retainer ring (12) is  
31 then screwed into place, the retainer ring (12) also  
32 being made from a drillable material, such as aluminium  
33 alloy. The retainer ring (12) has holes (13) which allow

1 fluid and mud to pass through the retainer ring (12) when  
2 tripping the shoe (1) to the bottom of the well bore.  
3 The eccentric nose (3) of the tool (1) may have hard  
4 facing (6) applied on the outside and may also have a  
5 float valve (14), as seen in Figure 4. The eccentric  
6 nose (3) also has a bore which is large enough to  
7 accommodate the ball (11) and is typically off-centre to  
8 ensure that any subsequent drill bit (not shown) to be  
9 passed through the tool (1) can drill through the ball.  
10 This prevents the ball (11) from acting as a bearing upon  
11 which the drill bit will spin on.  
12  
13 The assembly (1) can then be fitted onto the end of an  
14 expandable casing (not shown) and run into a pre-drilled  
15 well bore to the end of the section of well bore which  
16 has already been drilled and cased. At the end of the  
17 existing casing string, the tool (1) is activated just  
18 after the new casing enters the new drilled hole section,  
19 ie with the tool (1) in the rat hole below the existing  
20 casing. This is achieved by applying power to mud pumps  
21 (not shown), attached at the surface and to the top of  
22 the pipe used for running the expandable casing. The  
23 flow of mud in the first few seconds seats the ball (11)  
24 into the piston (4), if it is not already in this  
25 location. By applying static pressure thereafter, the  
26 ball (11) will seal off the piston bore (5) and pressure  
27 will be applied across the full area of the external seal  
28 on the piston (4). Thus the piston (4) is encouraged to  
29 move down the bore (5) of the body (2) of the tool and in  
30 doing so deforms the plurality of blades (10) outwards,  
31 by virtue of each of the blades (10) communicating with  
32 its corresponding ramp segment (7). When the piston (4)  
33 is moved down the bore (5) to the body (2), the ball (11)

1 will rest in position in a seat (18) as shown on the  
2 upper side of the centre line in Figure 1. When the ball  
3 (11) rests on the seat (18) in the position seen on the  
4 upper side of the centre line in Figure 1, the piston (4)  
5 is stationary and the blades (10) are expanded to gauge  
6 size. In this position, the split ring (6) fits into a  
7 corresponding groove (15), which prevents the piston (4)  
8 from moving. The retainer ring (12) has seals (16) which  
9 are external to the retainer ring (12). The retainer  
10 ring (12) has two seals which fit into grooves (not  
11 shown) on the external surface of the retainer ring (12).  
12 When the seals (16) on the outside of the retainer ring  
13 (12) travel past corresponding holes or ports (17) in the  
14 body (2), there is a pressure drop at the surface which  
15 indicates that the blades (14) are at their gauge size.

16  
17 By continuing to pump dynamically flowing fluid through  
18 the body (2) via the holes (17) to the outside, a dynamic  
19 pressure drop will be created. This will normally be  
20 lower than the static head which is required to push the  
21 piston (4) to this position. However on increasing the  
22 pump flow rate, the dynamic pressure head will be  
23 increased to a level above the static pressure head which  
24 is required to move the piston (4). As a consequence and  
25 at a pre-determined calculated level, the ball (11) will  
26 be pushed through the bore and the seat (18) of the  
27 piston (4) upon which the ball sits and into a seat in  
28 the eccentric nose (3). Mud can then flow through the  
29 nose (3). Rotation of the string can then take place and  
30 reaming to the bottom can commence.

31

32 Figure 5 illustrates a float valve (14) which can be  
33 incorporated into the nose (3) of the tool (1). The

1 float valve (14) allows mud and cement to pass through  
2 the nose (3) through the nozzles (19) in the nose (3) of  
3 the reamer shoe (1) to the bottom of the well, so that it  
4 can be displaced between the exterior surface of the  
5 casing and the interior surface of the well bore, to  
6 allow the casing to be cemented in place. However, the  
7 float valve (14) also ensures that cement cannot flow  
8 back into the reamer shoe through the nose although there  
9 would be some leakage through the pressure relief holes  
10 in the body adjacent to the retainer ring but the  
11 diametrical gap between the retainer ring and the body  
12 would be very small.

13  
14 When reaming is completed, the nose (3), piston (4),  
15 split ring (6), ball (11) and retainer ring (12) and  
16 inside portion of the ramp segments can be drilled out  
17 with the drill bit (not shown), with a gauge diameter  
18 slightly smaller than the bore (5) of the body (2). The  
19 design of the ramp segments located in the wall of the  
20 body and welded to the piston prevents the piston and  
21 retainer ring spinning when being drilled out. The body  
22 (2) could also be expanded after drill out, by pushing a  
23 pig or plug from above the reamer shoe (1). Note that a  
24 seat for a hydraulic expansion seal dart could also be  
25 located in the reamer shoe including at the entry to the  
26 nose designed in this case so that the ball would still  
27 pass by or through it, with the ball seat in the guide  
28 end of the nose.

29  
30 Figure 4 illustrates one embodiment of the invention,  
31 which allows the blades (10) to be retracted after use,  
32 wherein each of the blades (10) is adapted to correspond  
33 with a ramp section (7) by a dovetail groove (20). The

1   retainer ring (12) is provided with a profiled end which  
2   accommodates a retriever pulling tool (not shown), such  
3   as an overshot or spear. The retriever pulling tool can  
4   be used to pull the piston (4) back into its original  
5   position, hence pulling the blades (10) back into the  
6   body (2). Figure 5 illustrates a retainer ring (12)  
7   which is adapted to suit a spear (21). Figure 6  
8   illustrates a retainer ring (12) which is adapted with an  
9   end to suit an overshot (22). It will be appreciated  
10  that de-latching of the overshot or spear will also be  
11  required in the event that it is desirable to pull back  
12  the casing string for any reason after reaming has  
13  commenced.

14  
15  The tool (1) is designed to be welded while being  
16  assembled and manufactured, so that the amount of  
17  components within the internal bore (5) is minimised, and  
18  accordingly there are less internal parts which need to  
19  be drilled out for the next section of expandable casing.

20  
21  The advantage of the above described embodiment lies in  
22  the fact that it is possible to drill through the  
23  expandable reamer shoe (1) after having reamed the  
24  expandable casing to the bottom, and following expansion  
25  and cementing of the expandable casing. However, it is  
26  also recognised in this invention that the reamer shoe  
27  (1) could be designed to act solely as a drift for the  
28  drilled hole or as a drift in addition to being a reamer  
29  shoe. Where the tool (1) is to be used as a drift, its  
30  dimensions are slightly smaller than that of the outside  
31  diameter of the drilled hole, and the tool will not  
32  comprise cutting grade hard facing. It is also

1 recognised that the tool (1) could also be used with  
2 standard casing as opposed to expandable casing.

3

4 An alternative second embodiment of the reamer shoe is  
5 shown in Figure 8, generally depicted at 23. The shoe  
6 (23) is made entirely from steel and is millable as  
7 opposed to drillable. The shoe (23) can also be  
8 retrieved back to the surface if required. The reamer  
9 shoe (23) can also be used with a final casing string,  
10 for example in a section which does not require drill-  
11 out.

12

13 The body (24) of the tool has three pockets each of which  
14 holds a blade (25) with hard metal or super hard metal or  
15 diamond, or other cutting grade material on the external  
16 surface, as shown in Figures 11 and 12. It will be  
17 appreciated that the cutting grade material will not be  
18 included on the blade (25) if the reamer shoe (23) is to  
19 be used as a drift only. The blades (25) are activated  
20 by the flow of fluid through the ports or nozzles (26) in  
21 the eccentric nose (27) of the tool (23) which creates a  
22 dynamic pressure drop between the inside and outside of  
23 the tool (23). This forces the blades (25) out against  
24 leaf springs (28) which are mounted in additional pockets  
25 along the length of the sides of the blades (25). Each  
26 blade (25) has a series of blade pistons (29) which are  
27 screwed into the base of the pockets of the body (24).  
28 The blades (25) are driven out to the gauge diameter by  
29 the dynamic pressure drop, against stop blocks (30) which  
30 are located at either end of each of the blades (25).  
31 The blades (25) are locked in place by the spring  
32 activated blocks (30), and reaming then commences to the  
33 bottom of the bore. A means to indicate that the blades

1 (25) are at the gauge size could be achieved by adding a  
2 pressure relief valve (not shown). The leaf springs (28)  
3 hold the blades (25) into the body (24) when the tool  
4 (23) is tripped into the hole. Figure 9 illustrates a  
5 cross section of the body (24) when the blades (25) are  
6 closed. Figure 10 illustrates the same cross section of  
7 the body (24) when the blades are expanded.  
8

9 If the tool (23) is to be used on the final string of  
10 casing, the tool can be left in-situ without being  
11 drilled out. In addition, a float valve (31) can be  
12 fitted to the eccentric nose (27) of the tool (23) to aid  
13 cementing. Figure 10 illustrates the float valve (31)  
14 wherein the valve is closed thereby obturating the entry  
15 of fluid such as cement or mud from the body (24) of the  
16 tool (23) into the nose (27). Figure 12 shows the float  
17 valve (31) when open, which allows fluid to flow into the  
18 nose (27) when reaming. If a float valve (31) is not  
19 fitted to the nose (27), the nose (27) can be made  
20 integrally with the body (24).  
21

22 The casing can be retrieved at any time while reaming, by  
23 pulling the casing string uphole until the blades (25)  
24 bear against the end of the shoe of the last casing  
25 string, and by applying tension to the string from the  
26 surface. This will push the blades (25) into the body  
27 (24) by shearing the spring activated blocks (30). A  
28 bursting disk (32) may also be incorporated into the body  
29 (24) of the tool to increase the flow area through the  
30 tool for cementing. It is envisaged that a bursting disk  
31 (32) will be incorporated into the shoe (23) if the  
32 nozzles (26) of the nose (27) are small. Incorporation  
33 of the bursting disk will ensure that a reasonably high

1 cross sectional flow area is available for cement to pass  
2 through. When using a burst disk it is likely that the  
3 nose will not incorporate a float valve as the cement  
4 could flow back in through the hole after the disc was  
5 burst. In this case the float valve would be fitted  
6 above the burst disc location.

7  
8 An advantage of the present invention is that the reamer  
9 shoe can be expanded prior to the passage of expandable  
10 casing which will ensure that the casing can expand fully  
11 to the desired gauge size. A further advantage is that  
12 the reamer shoe may be drilled through by a subsequent  
13 drill bit or casing drill shoe with the first embodiment  
14 design. This allows further sections of a well-bore to  
15 be drilled below the region which has been lined by the  
16 expandable casing, without any damage to the drill bit.  
17 The expandable reamer shoe can also be advanced into the  
18 borehole by reciprocation and/or rotation.

19  
20 Further modifications and improvements may be  
21 incorporated without departing from the scope of the  
22 invention herein intended.

1 CLAIMS

2

3 1. An expandable reamer shoe for mounting on a casing  
4 string, the shoe having a body upon which are  
5 arranged a plurality of reaming members wherein said  
6 reamer shoe is substantially constructed from a  
7 relatively soft drillable material, wherein the  
8 plurality of reaming members are moveable between a  
9 first and second position, and wherein the reaming  
10 members are closed in a first position and expanded  
11 in a second position.

12

13 2. An expandable reamer shoe as claimed in Claim 1,  
14 wherein the plurality of reaming members are in the  
15 form of blades.

16

17 3. An expandable reamer shoe as claimed in Claim 2,  
18 wherein each of the blades has a hard facing applied  
19 to an outer surface.

20

21 4. An expandable reamer shoe as claimed in any  
22 preceding Claim, wherein the reaming members move  
23 from the first closed position to the second  
24 expanded position by virtue of movement of an  
25 activating piston.

26

27 5. An expandable reamer shoe as claimed in Claim 4,  
28 wherein said activating piston defines an internal  
29 bore.

30

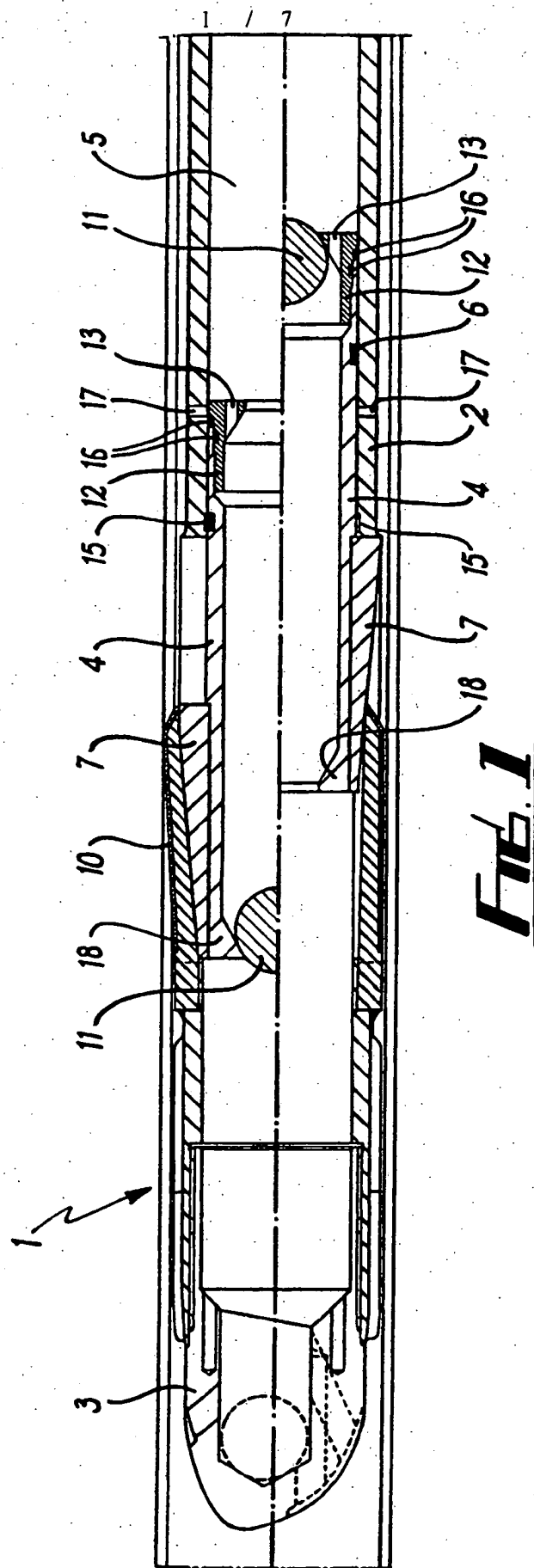
31 6. An expandable reamer shoe as claimed in Claim 4 or  
32 Claim 5, wherein movement of the activating piston  
33 is provided by an increase in hydrostatic pressure.

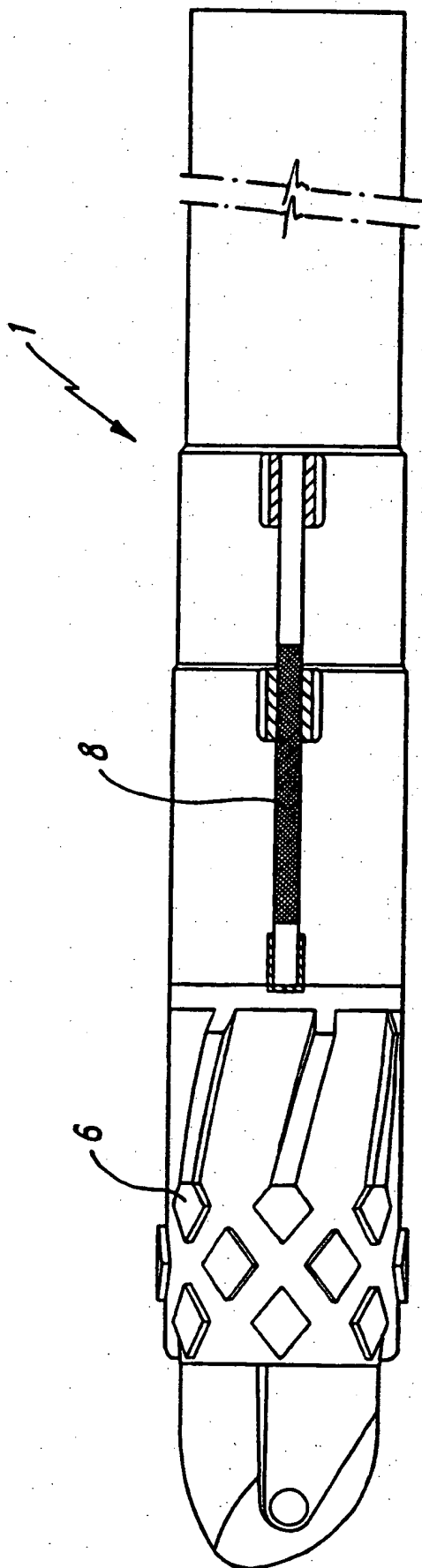
- 1
- 2 7. An expandable reamer shoe as claimed in Claim 6,
- 3 wherein the increase in hydrostatic pressure is
- 4 provided by an obstructing means within the internal
- 5 bore of the activating piston.
- 6
- 7 8. An expandable reamer shoe as claimed in Claim 7,
- 8 wherein said obstructing means is a deformable ball
- 9 or dart.
- 10
- 11 9. An expandable reamer shoe as claimed in Claim 8,
- 12 wherein the reaming members are fully expanded when
- 13 the ball/dart communicates with a seat formation in
- 14 the internal bore.
- 15
- 16 10. An expandable reamer shoe as claimed in Claim 8 or
- 17 Claim 9, wherein the ball/dart is held inside the
- 18 bore of the activating piston by a retainer ring.
- 19
- 20 11. An expandable reamer shoe as claimed in Claim 10,
- 21 wherein the retainer ring has a plurality of by-pass
- 22 ports which allow fluid and mud to pass through the
- 23 retainer ring.
- 24
- 25 12. An expandable reamer shoe as claimed in any one of
- 26 Claim 4 to Claim 11, wherein the activating piston
- 27 is adapted to receive a retrieval tool such as a
- 28 spear or overshot.
- 29
- 30 13. An expandable reamer shoe as claimed in Claim 10 or
- 31 Claim 11, wherein the retainer ring is adapted to
- 32 receive a retrieval tool, such as a spear or
- 33 overshot.

- 1  
2 14. An expandable reamer shoe as claimed in any of Claim  
3 4 to Claim 13, wherein the activating piston has an  
4 external split ring mounted around an outside  
5 diameter.  
6
- 7 15. An expandable reamer shoe as claimed in Claim 14,  
8 wherein the split ring can communicate with a groove  
9 in the body of the reamer shoe, wherein the  
10 activating piston is prevented from moving when the  
11 split ring is in communication with said groove.  
12
- 13 16. An expandable reamer shoe as claimed in any one of  
14 Claim 4 to Claim 15, wherein a plurality of ramps  
15 are located externally to the activating piston.  
16
- 17 17. An expandable reamer shoe as claimed in any one of  
18 Claim 1 to Claim 3, wherein the reaming members move  
19 from the first closed position to the second  
20 expanded position by virtue of a hydrodynamic  
21 pressure drop between an interior and exterior of  
22 the reamer shoe.  
23
- 24 18. An expandable reamer shoe as claimed in Claim 16,  
25 wherein said hydrodynamic pressure drop is created  
26 by one or more nozzles attached to a lowermost end  
27 of the reamer shoe.  
28
- 29 19. An expandable reamer shoe as claimed in any  
30 preceding Claim, wherein the reaming members are  
31 held in the first closed position by a plurality of  
32 leaf springs.  
33

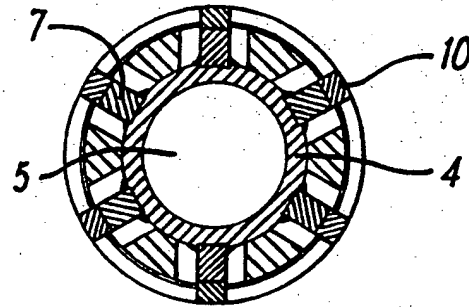
- 1 20. An expandable reamer shoe as claimed in any  
2 preceding Claim, wherein in the second expanded  
3 position the reaming members are locked in position  
4 by a first and second retaining block at each end of  
5 the reaming member(s).  
6
- 7 21. An expandable reamer shoe as claimed in any  
8 preceding Claim, wherein the reamer shoe includes a  
9 rupture means such as a burst disc which permits  
10 increased fluid flow from an interior of the reamer  
11 shoe to the exterior of the reamer shoe.  
12
- 13 22. An expandable reamer shoe as claimed in any  
14 preceding Claim, wherein the expandable reamer shoe  
15 includes a cementing float valve.  
16
- 17 23. A method of inserting expandable casing into a  
18 borehole, comprising the steps of:  
19
- 20 (a) running a first section of expandable casing  
21 into a pre-drilled borehole;  
22
- 23 (b) expanding the first section of expandable  
24 casing in place;  
25
- 26 (c) underreaming under the in-place first section  
27 of expanded casing using a standard underreamer  
28 and bit;  
29
- 30 (d) running a second section of expandable casing  
31 through the first section of expandable casing  
32 with an expandable reamer shoe; and  
33

- 1 (e) reaming down the borehole by rotation and/or  
2 reciprocation of the expandable reamer shoe to  
3 an expected size.  
4
- 5 24. A method as claimed in Claim 23, wherein the method  
6 includes the step of drifting the expandable reamer  
7 shoe.  
8
- 9 25. A method as claimed in Claim 23 or Claim 24, wherein  
10 the method includes the step of expanding the second  
11 section of expandable casing into the reamed  
12 borehole.  
13
- 14 26. A method as claimed in any one of Claims 23 to 25,  
15 wherein the method includes the step of cementing  
16 the expandable casing.  
17
- 18 27. A method as claimed in any one of Claims 23 to 26,  
19 wherein the expandable reamer shoe is as claimed in  
20 any one of Claims 1 to 22.  
21
- 22 28. A method as claimed in any one of Claims 23 to 26,  
23 wherein the method includes the step of expanding  
24 the body of the expandable reamer shoe.  
25
- 26 29. A method as claimed any one of Claims 23 to 27,  
27 wherein the method includes the step of drilling  
28 through the expandable reamer shoe prior to running  
29 a subsequent section of expandable casing through an  
30 in-place section of expandable casing.  
31

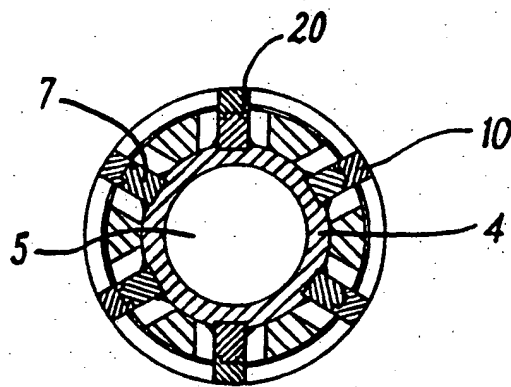




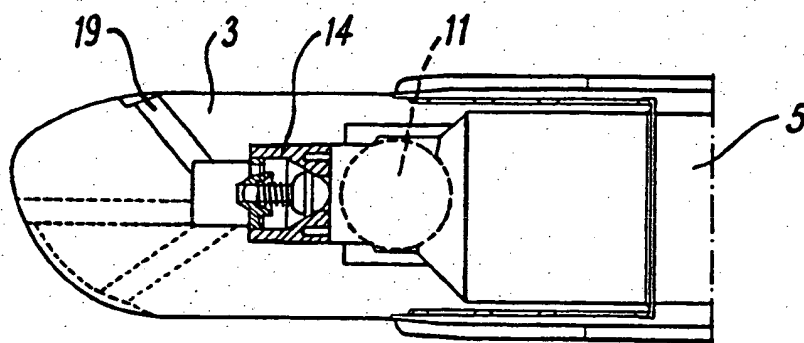
**Fig. 2**



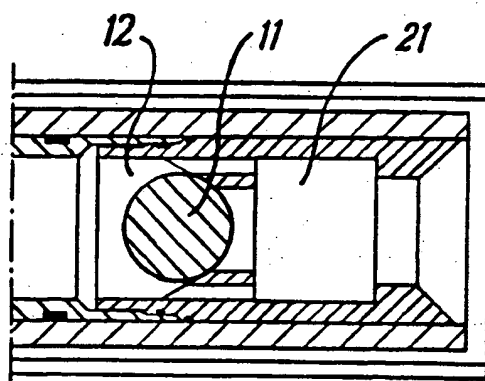
**FIG. 3**



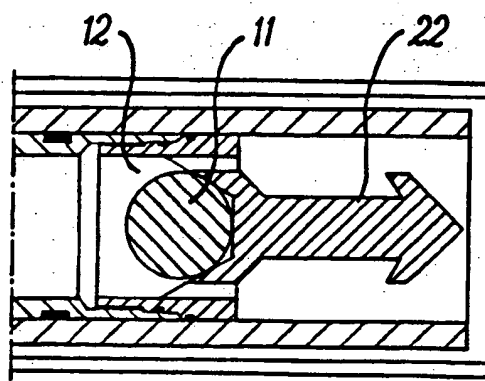
**FIG. 4**



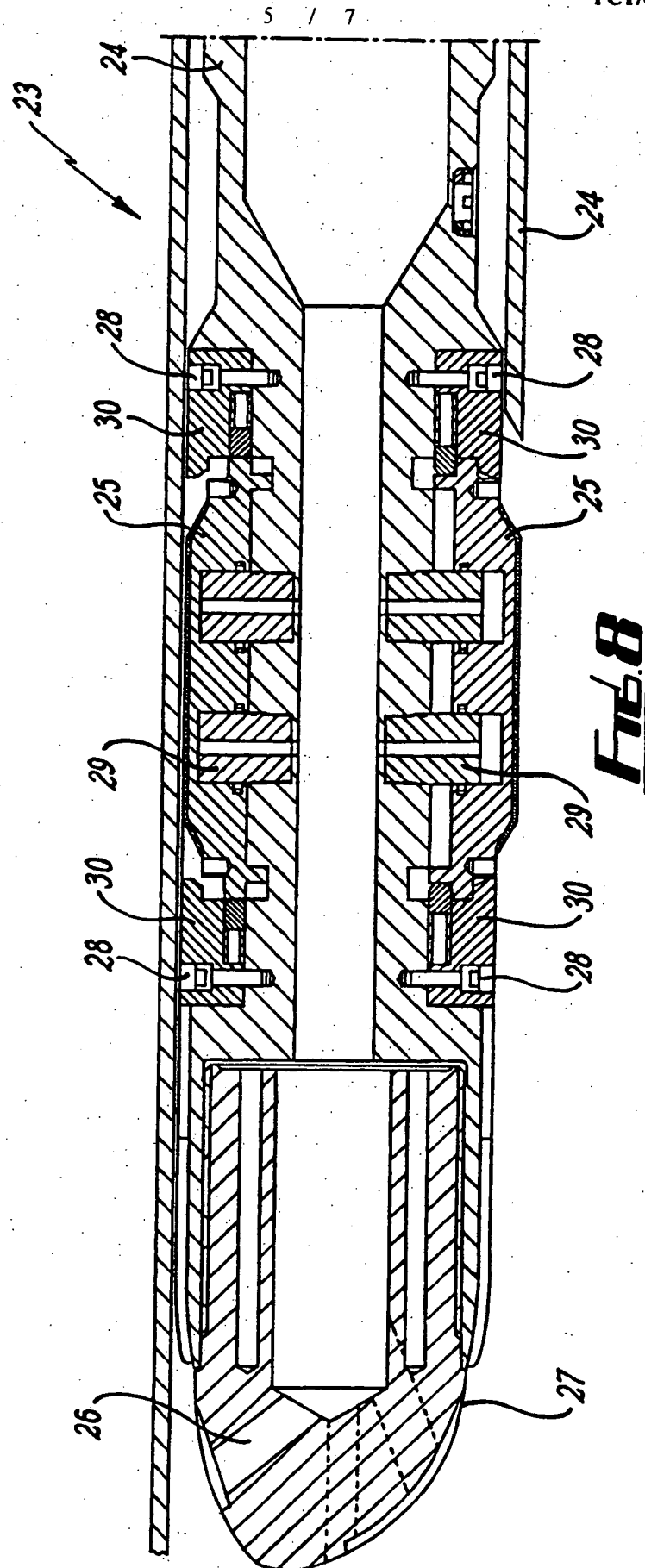
**Fig. 5**

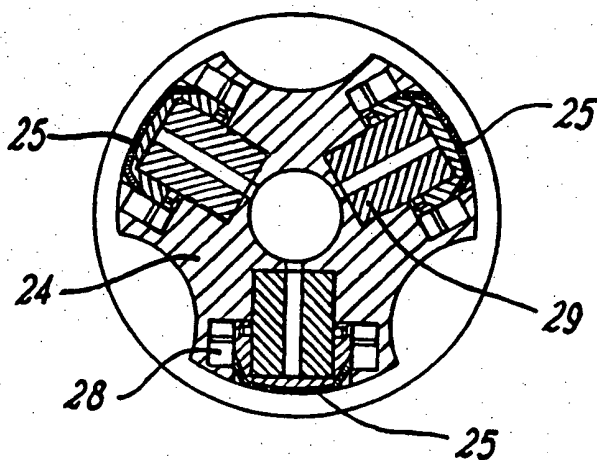


**Fig. 6**

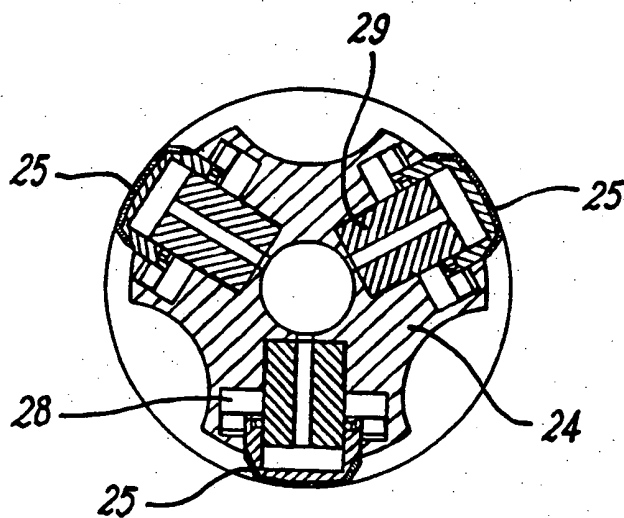


**Fig. 7**

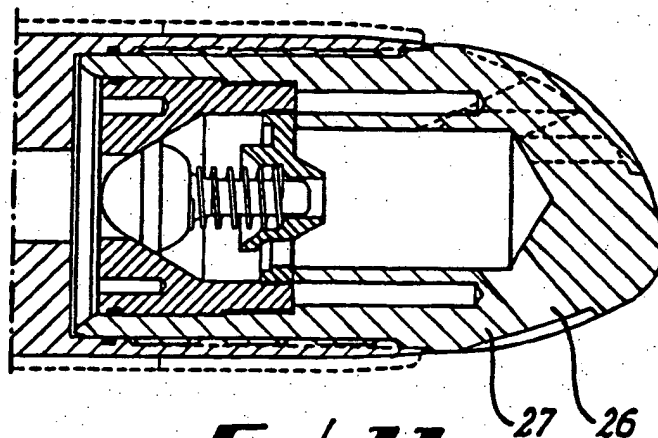




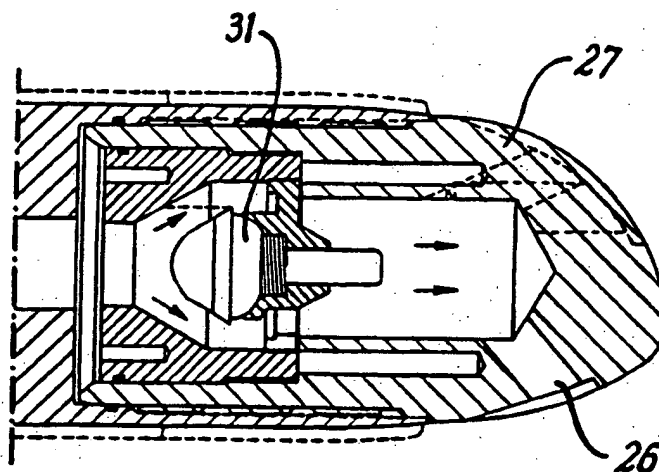
**FIG. 9**



**FIG. 10**



**FIG. 11**



**FIG. 12**

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 01/01512

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC 7 E21B7/20 E21B17/14 E21B43/10				
According to International Patent Classification (IPC) or to both national classification and IPC				
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) IPC 7 E21B				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data				
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>				
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
Y	US 3 552 510 A (BROWN CICERO C) 5 January 1971 (1971-01-05)  column 6, line 35 - line 48; figures 1,2	1-8, 16-18, 20,23, 25-27		
Y	WO 99 64713 A (WARDLEY MICHAEL ;BBL DOWNHOLE TOOLS LTD (GB)) 16 December 1999 (1999-12-16) page 8, line 11 -page 9, line 8	1-8, 16-18, 20,27		
Y	US 5 361 859 A (TIBBITTS GORDON A) 8 November 1994 (1994-11-08) column 5, line 35 - line 46; figure 1  -/-	16		
<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C.				
<input checked="" type="checkbox"/> Patent family members are listed in annex.				
<b>* Special categories of cited documents:</b> <table border="0"> <tr> <td>           *A* document defining the general state of the art which is not considered to be of particular relevance            *E* earlier document but published on or after the international filing date            *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)            *O* document referring to an oral disclosure, use, exhibition or other means            *P* document published prior to the international filing date but later than the priority date claimed         </td> <td>           *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention            *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone            *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.            *Z* document member of the same patent family         </td> </tr> </table>			*A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *Z* document member of the same patent family
*A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *Z* document member of the same patent family			
Date of the actual completion of the international search  11 July 2001		Date of mailing of the international search report  19/07/2001		
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer  Garrido Garcia, M		

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 01/01512

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FR 2 741 907 A (DRILLFLEX) 6 June 1997 (1997-06-06) page 4, line 3 - line 33 page 6, line 3 - line 12	23,25-27
A	WO 96 28635 A (BRIT BIT LIMITED ;STRONG PHILLIP (GB); WARDLEY MICHAEL (GB)) 19 September 1996 (1996-09-19) page 9, line 12 - line 22	1-29
A	GB 2 333 542 A (DOWNHOLE PRODUCTS PLC) 28 July 1999 (1999-07-28) abstract	1-29

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 01/01512

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3552510	A	05-01-1971	NONE	
WO 9964713	A	16-12-1999	AU 4279499 A EP 1086292 A NO 20006303 A	30-12-1999 28-03-2001 15-12-2000
US 5361859	A	08-11-1994	BE 1010105 A GB 2275067 A,B GB 2301386 A,B US 5560440 A	02-12-1997 17-08-1994 04-12-1996 01-10-1996
FR 2741907	A	06-06-1997	NONE	
WO 9628635	A	19-09-1996	AT 174403 T AU 713736 B AU 4950396 A CA 2214749 A DE 69601129 D EP 0815342 A NO 974181 A US 6062326 A	15-12-1998 09-12-1999 02-10-1996 19-09-1996 21-01-1999 07-01-1998 05-11-1997 16-05-2000
GB 2333542	A	28-07-1999	AU 2172699 A EP 0995008 A WO 9937881 A GB 2339227 A	09-08-1999 26-04-2000 29-07-1999 19-01-2000

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**

**THIS PAGE BLANK (USPTO)**